Methods: A 3D-Atrium Stent model was created in Solidworks 2014 (DS Solidworks Corp, Waltham, Mass). A laser-cut tube was fabricated to strut dimensions and stent length (38 mm) taken from microscopic photographs. A straight arterial model of 40 mm in length was created using lumen dimensions from computed tomography scanned data. The stent was inserted to 40% coverage within the SMA. These models were imported and meshed in Abaqus 6.13 (Dassault Systemes Simulia Corp, Providence, RI). Surface-to-surface contact between the stent and the balloon, self-contact, and stent-to-arterial lumen was used between the stent using the Lagrangian penalty method. Nonlinear hyperelastic material properties were derived using a five-parameter strain energy function in Abaqus 6.13. 316L stainless steel stress strain data was used for the stent. The balloon and SMA was constrained to expand only in the radial direction, $u_\theta = u_Z = 0$. The boundary conditions, $u_\theta = u_Z = 0$, were applied to the stent at the central midpoints. The stent and stent-in-artery simulation process occurred in four steps: (1) stent crimping, (2) stent relaxation, (3) stent expansion, and (4) stent relaxation.

Results: The analysis showed plastic yielding of the struts at the crown sections causing the stent to "lock" into a fixed position that was determined by using the von Mises yielding criterion and analyzing the strain formulation throughout these regions. Elastic recoil does occur in the model of <5% and foreshortening <5%. The crown regions show a "fish scaling" effect. Higher stresses were generated at the regions of stent contact between the stent and the intimal surface. The von Mises stress range was 6 to 42 kPa, with the outside of the artery showing a stress range of 3 to 6 kPa (Fig). The expanded stent into the arterial vessel shows a mapped stress distribution <2 MPa along the luminal wall for circumferential, radial, and axial stresses.

Conclusions: The Atrium stent plastically deforms to a fixed position with minimal elastic recoil, without arterial interactions. More recoil is experienced with the addition of the SMA. The use of finite element analysis has shown the stent can retain an open position for blood flow while maintaining higher stress distributions localized at the crown regions and edge of the stent in contact with the lumen of the intimal layer. The impact of these stresses is the focus of continuing research. The expansion and relaxation of the stent, with areas of high stress, could lead to an inflammatory response and possible intimal hyperplasia.

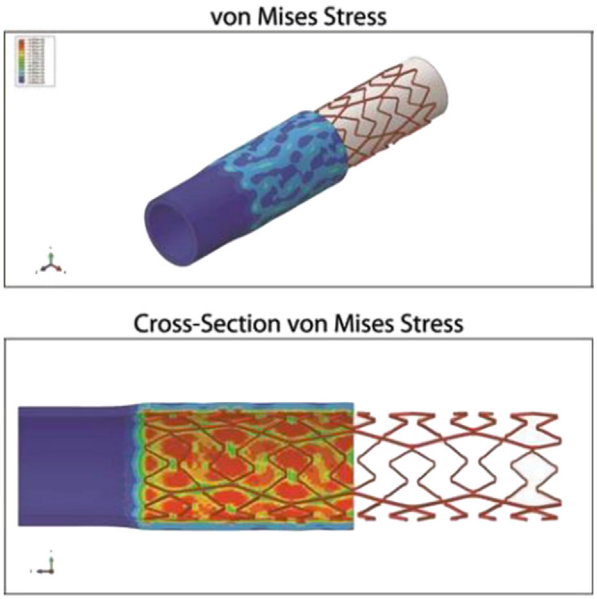

Fig. The stent was expanded to a 3mm balloon diameter showing (A) the von Mises Stress distribution with stent plastic yielding shown in *red* and higher localized von Mises stresses at the intima and medial layer at stent crown regions.

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Novel Endovascular Management of Bilateral Congenital Renal Arteriovenous Malformations: Case Report and Clinical Review

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Introduction: We report the successful treatment of a 39-year-old man presenting with congenital renal arteriovenous malformations (AVMs). The AVMs were initially suspected from auscultation of a flank bruit and confirmed by multiple imaging modalities. The clinical presentation included headaches, hypertension, and reduced exercise tolerance.

Methods: Imaging revealed bilateral high-flow AVMs in the lower poles of the kidneys (Fig 1). With arteriography, the normal renal parenchyma failed to visualize secondary to the high-flow steal of the AVMs. The inferior vena cava (IVC) measured 5.5 cm secondary to the increased volume. The AVM on the right measured 14 cm × 11 cm. The AVM on the left measured 4 cm × 4 cm.

Results: The left renal AVM was treated first with standard coil embolization techniques. Renal function scans were obtained at each stage of the management and remained unchanged. Standard attempts at coil embolization of the larger right cavernous renal AVM were unsuccessful, with rapid movement of the largest available constrained embolization devices through the AVM into the IVC. Successful occlusion of the AVM was accomplished using novel endovascular techniques. Balloon occlusion of the venous outflow was performed via a right internal jugular approach. Two self-expanding 10-mm carotid Wallstents were deployed horizontally into the AVM and used as a scaffold for additional embolization coils (Fig 2). Postprocedural ultrasound examination demonstrated successful occlusion of the AVMs with normalization of the IVC diameter. At 18 months of follow-up, the patient's headaches resolved, his blood pressure was well controlled, and his renal function and exercise tolerance returned to normal. We will discuss the clinical manifestations and surgical and endovascular alternatives for management of renal AVMs.

Conclusions: We report a novel endovascular technique for management of bilateral renal AVMs.

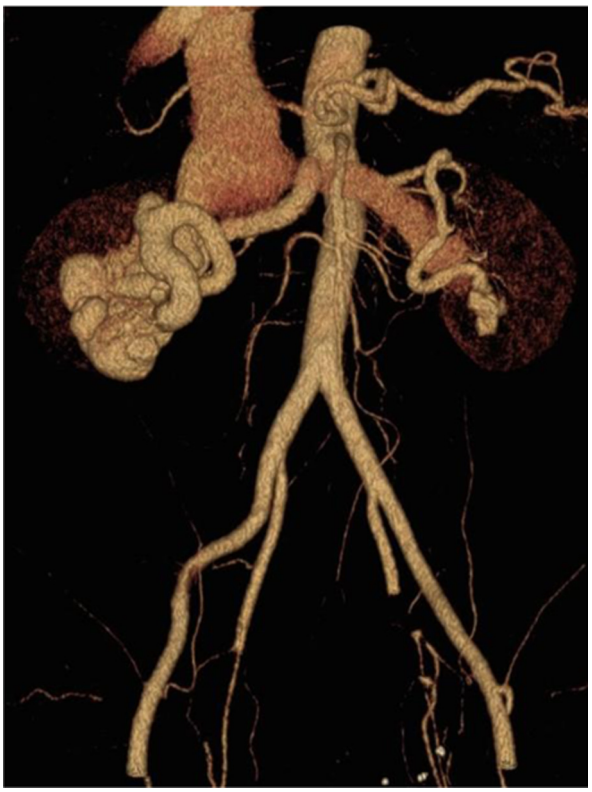

Fig 1. Preoperative three-dimesional reconstruction of computerized axial tomogram showing bilateral renal arteriovenous malformations (AVMs) with dilation of the left renal vein and inferior vena cava.

Fig 2. Completion digital subtraction angiography showing successful embolization of bilateral renal arteriovenous malformations (AVMs).

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Is Left Renal Vein Ligation Benign? A Novel Method for Maintaining Left Renal Venous Outflow During Extensive Inferior Vena Caval Resection.

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Introduction: Ligation of the left renal vein (LRV) has been felt to be a relatively benign maneuver, with renal venous outflow maintained through existing venous branches. LRV has shown to be of negligible in long-term renal function in the setting of aneurysm repair with dual kidneys; the effect of LRV in the setting of a solitary left kidney, however, is less well described. Case reports, primarily in the urology literature, have described sudden deterioration in renal function with LRV during right nephrectomy, and hence, the consequences of acute LRV might better be described as "unpredictable." This report describes a patient who suffered rapid renal deterioration from left renal vein obstruction secondary to recurrent renal cell carcinoma, underwent extensive inferior vena cava (IVC) resection, and on whom a novel method for intraoperative maintenance of left renal venous drainage during level III vena caval resection was used.

Methods: The patient, a 62-year-old man evaluated for rapidly progressive lower extremity edema, had undergone laparoscopic right nephrectomy 9 years earlier without venous or extrarenal spread. An echocardiogram noted a mass in the IVC, and subsequent magnetic resonance imaging demonstrated a suspected recurrent tumor involving the IVC and extending to the level of the right hepatic vein. Creatinine had concomitantly risen from 1.2 to 2.9 mg/dL during an 8-day period. The left renal vein was patent, with some flow into IVC along with patent left gonadal, adrenal, and lumbar veins. Results of a metastatic survey were negative. The patient was offered IVC resection. Exposure was performed through a right thoracoabdominal incision, with confirmation of tumor extent and absence of metastases. The left renal vein was extensively mobilized, and caval resection and reconstruction from the L3 level to right hepatic vein was planned. A venovenous circuit was created using percutaneously placed cannulas in the right common femoral and right internal jugular veins. With concerns for further compromise of renal function from even temporary renal vein occlusion, a 24F right-angle single-stage venous cannula was placed in the left renal vein, and bypass with left renal vein decompression was instituted using full-heparinization. Potentially curative resection was performed uneventfully, and the IVC was reconstructed using a 24-mm Dacron graft with a 10-mm sidearm left renal graft. Total bypass time was 139 minutes, and urine output during the bypass period was 240 mL.

Results: Excellent urine output was seen throughout the perioperative period, with creatinine returning to value of 1.1 mg/dL by postoperative day 5. The patient was discharged on postoperative day 7. Postoperative venous-phase computed tomography has demonstrated patent IVC and left renal vein interposition grafts.

Conclusions: The effect of LRV with a solitary left kidney is unpredictable; the negligible effects of LRV after aneurysm repair may be more an effect of right kidney compensation rather than a reflection on the benignity of LRV. When planning pararenal vena caval resection and reconstruction, reconstruction of the left renal vein is advisable, and intraoperative renal function can be optimized using the renal vein drainage technique described above.

Author Disclosures: C. S. Kiell: None; **A. R. Barksdale:** None.

Endostaples for Distal Fixation in a Thoracic Endovascular Aortic Aneurysm Repair (TEVAR)

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Introduction: We report the case of 77-year-old woman with an asymptomatic enlarging distal thoracic aortic aneurysm (TAA) treated with endovascular repair using endostaples.

Methods: The patient was a former smoker with a history of hypertension, chronic kidney disease, asthma, and hypothyroidism. Physical examination was significant for a pulsatile mass in the midabdomen. She was followed up with serial computed tomography angiography (CTA) for 5 years. The TAA measured 3.8 cm in 2009, enlarging to 5.5 cm in 2013. CTA revealed a short distal neck ~5 mm proximal to the celiac axis. Therefore, the decision was made to use endostaples for distal fixation.

Results: After informed consent, the patient was taken to the operating room. A 7F sheath was inserted via a right femoral exposure. The left common femoral artery was accessed percutaneously. An aortogram confirmed a short distal neck. The celiac artery was selected with a guidewire, and access was maintained in the hepatic artery with a glide catheter. A Cook Zenith TX2 28-mm × 80-mm endograft (Cook Medical, Bloomington, Ind) was deployed. Four Aptus Heli-FX Thoracic EndoAnchors (Aptus Endosystems Inc, Sunnyvale, Calif) were placed at 2, 4, 8, and 10 o'clock. A completion angiogram showed no endoleak and good filling of the celiac artery. The patient tolerated the procedure well, without any complications. She was discharged the next day, and remained well at the 2-month follow-up. A CTA at the 2-month follow-up confirmed good placement of graft, with no endoleak, and the aneurysm was completely excluded.

Conclusions: There are multiple options for obtaining distal fixation during thoracic endovascular aortic repair. These include coverage of the celiac axis, barbs/hooks on the graft, distal graft visceral uncovered bare-metal stents, fenestrated/scalloped stent grafts, branched endografts, parallel stenting (chimney, snorkel, or periscope), and endoanchors, endostaples, and endoscrews. This case is an example of a distal TAA with difficult anatomy due to a short distal neck treated with endovascular repair using endostaples to ensure distal fixation and reduce the risk of migration. Endostaples can serve as a safe and viable alternative that is minimally invasive for handling short landing zones. Early results with endostaples are promising, but further studies are warranted to evaluate long-term safety and durability. The ANCHOR registry is designed to evaluate patients from multiple sites treated with the Aptus Heli-FX EndoAnchor System and is currently enrolling.

Author Disclosures: R. C. Medicherla: None; **E. Lipsitz:** None.

Current Accepted Hemodynamic Criteria for Critical Limb Ischemia (CLI) Do Not Accurately Stratify Patients at High Risk for Limb Loss

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Introduction: Critical limb ischemia (CLI) has been defined as patients with rest pain or tissue loss who have an ankle pressure (AP) <70 mm Hg or toe pressure (TP) <50 mm Hg. Data suggesting these patients are at high risk for limb loss without successful revascularization are limited. This study was designed to identify limb loss and mortality rates in patients who did not respond to revascularization or who were not revascularized and to determine whether CLI hemodynamic criteria accurately identify patients at high risk for limb loss.

Methods: Between 2008 and 2010, all patients undergoing lower extremity arterial duplex testing at our hospital were identified. Those with an AP <70 mm Hg or TP <50 mm Hg were retrospectively reviewed to determine whether they had symptoms of rest pain or tissue loss qualifying them for analysis in the database. Patients who underwent revascularization and